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Correspondence:
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365 Ramses St- Ain Shams University, Faculty of Specific Education
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جامعة عين شمس، كلية التربية النوعية، القاهرة، مصر

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يسر **معامل التأثير والاستشهادات المرجعية للمجلات العلمية العربية (ارسيف – ARCIF)**، أحد مبادرات قاعدة بيانات "**معرفة**" للإنتاج والمحتوى العلمي، إعلامكم بأنه قد **أطلق التقرير السنوي الثامن للمجلات للعام 2023**.

ويسرنا تهنئتكم وإعلامكم بأن **المجلة المصرية للدراسات المتخصصة** الصادرة عن **جامعة عين شمس، كلية التربية النوعية، القاهرة، مصر، قد نجحت في تحقيق معايير اعتماد معامل "ارسيف Arcif"** المتوافقة مع المعايير العالمية، والتي يبلغ عددها **(32) معياراً**، وللاطلاع على هذه المعايير يمكنكم الدخول إلى الرابط التالي:

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+962 6 5548228 -9
+ 962 6 55 19 10 7
info@e-marefa.net
www.e-marefa.net
Amman - Jordan
2351 Amman, 11953 Jordan

محتويات العدد

تابع محتويات العدد

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* بحوث علمية محكمة باللغة الإنجليزية :

Applying Mobile Learning for Academic Achievement and Behavioral, Cognitive, and Emotional Engagement in Chemistry among High School Students

Dr. Fadwa Yasin Flemban [(1)]

Tahani Saed Al- Awfi [(2)]

(1) Asst.Prof. of Educational Technology College of Education, King Abdulaziz University.
(2) Chemistry teacher and researcher in educational technology.

Applying Mobile Learning for Academic Achievement and Behavioral, Cognitive, and Emotional Engagement in Chemistry among High School Students

Fadwa Yasin Flemban, Tahani Saed Al-Awfi

Abstract

This study aimed to identify the effect of mobile learning on first-year high school students while teaching them how to build chemical particle models. It examined four dependent variables: academic achievement and behavioral, cognitive, and emotional engagement. Therefore, 20 female students were selected from the first year of high school and trained to utilize a mobile learning tool called Happy Atoms. A quasi-experimental design and a descriptive approach have been applied to interpret this study's results. A pretest and post-test were designed to determine the extent to which students acquire scientific knowledge. In addition, an observation card was prepared and used to record three dimensions of students' engagement (behavioral, cognitive, and emotional). This study showed a positive effect of using the Happy Atoms tool on the student's academic achievement and overall engagement, particularly their emotional involvement. Based on that, using tablets to learn and teach chemistry topics, such as types of chemical links and electronic distribution, is recommended. The study also suggested utilizing other research methods, such as interviews and surveys, for students' perspectives on this learning tool.

Keywords: Mobile Learning, Academic Achievement, Learning Engagement, Chemical Molecules Models

Introduction

Currently, there are significant scientific and technical advancements taking place across a variety of fields. These necessitate adapting educational methods and activities to the technological revolution (Zeitoun, 2007, p. 662). Understanding chemistry is fundamental to comprehending different aspects of science, technology, and engineering. That indicates mastering chemistry courses is essential for learners of all ages (Balaban & Klein, 2006, p. 617). Abundant conferences have emphasized the importance of chemistry courses in various development fields. For example, the sixth conference of the Saudi Chemical Society aimed to draw attention towards the significance of chemistry and encouraged students to participate and exchange experiences in chemistry (Ministry of Interior, 2016).

Due to the numerous abstract and intricate scientific concepts in chemistry, it would be beneficial to utilize modern teaching methods and appropriate techniques to ensure students' visualization and comprehension (Nobes & Panagiotaki, 2007, p. 647). The development of technology, particularly wireless devices and mobile applications such as smartphones and tablets, has revolutionized the educational field. Thus, mobile learning has become a significant area of research and a crucial topic for educational institutions (Ally & Prieto-Blázquez, 2014, p. 143). Mobile learning has the potential to provide digital educational models to students, which can serve as sensory aids and foster a deeper understanding of abstract concepts. By incorporating these models into a learning environment, students can develop their critical thinking skills and curiosity more effectively. Such an approach can empower learners to view science as a constantly evolving and dynamic knowledge. It also enables them to comprehend and explain scientific phenomena more effectively (Zeitoun, 2007, p. 77).

In addition, seeking to improve student engagement in the educational process is demanding. It significantly impacts their chances of success and decreases the possibility of dropping out (Wesseling, 2016, p. 18). It also affects learning outcomes (Jimerson, Campos, & Greif, 2003, p. 12). Mobile technology provides many appropriate tools that help student interacts with others and allows them to remain connected to the educational environment for a longer time (Foroughi, 2015, p. 17). Mobile learning also provides an appropriate opportunity to acquire and build knowledge. It can positively affect students' academic achievement, performance, and motivation (Demir & Akpinar, 2018 p. 7). It has also influenced student engagement in several ways (Chametzky, 2014, p. 818). Students' involvement in learning is closely related to the amount of time and energy spent on the educational task, which positively affects academic achievement (Kuh, 2009, p. 5). It also helps shape their sentiments, influences their behavior and scientific orientations, and affects their cognitive development.

Therefore, this study examined the effect of applying mobile learning, presented on a learning tool called Happy Atoms, on first-year high school students' academic achievement and engagement in building models of chemical molecules in public schools in Makkah Al-Mukarramah City.

Research problem:

There is a broad trend towards designing non-traditional curricula and using interactive educational tools and activities to provide appropriate opportunities to engage students in their learning and achieve learning pleasure (Ally & Prieto-Blázquez, 2014, p. 145). Therefore, promoting a positive environment for teaching abstract concepts is necessary. To do that, taking advantage of the technology in education is a possible solution. Mobile technology has provided specific tools for studying chemistry, including molecule models presented to the learner as two- and three-dimensional models. Therefore, representational technologies can influence learner’s problem-solving techniques (McCollum, Sepulveda, & Moreno, 2016, p. 12). It has been found that mobile-based learning helps students identify visual representations and build up the microscopic dimension of their molecules. It also improves students' engagement while studying abstract molecule models (Uyulgan & Akkuzu, 2016, p. 65). Also, using these devices affects learners' academic performance and enhances their engagement in their learning environment, whether with others or with resources (Lowe, 2017, p. 17; Arnold, 2018, p. 122).

As one of this study's researchers works as a chemistry teacher, students constantly struggle to understand the infinitesimal things represented in learning chemistry, such as atoms, elements, and molecules. She also noticed students' limited perception and weak involvement while learning them. Understanding these infinitesimal things is necessary due to the existence of writing formulas of molecules in advanced chemistry curricula. There are essential topics in general chemistry that help students improve their knowledge in other areas of chemistry, such as organic chemistry and biochemistry (Burrows & Mooring, 2015, p. 19).

With the scientific concepts of chemistry and the abstraction and complexity of most of them, there is an urgent need to help teachers teach and students learn these concepts (Zeitoun, 2007, p. 491). Among the helpful means are educational models, which have a significant role in clarifying abstract concepts - such as the concept of the atom and molecule. When these abstract concepts are represented by physical evidence to appear in their three dimensions, learners can visualize and understand them through theoretical descriptions (Oh & Oh, 2011, p. 1115). Molecular models are essential scientific concepts, as the student is expected to interpret symbolic representations and be able to synthesize chemical bonds correctly. By tracking the conceptual perception of molecular models among students, studies have shown that many students had misconceptions about them and difficulties in determining their structure (Burrows & Mooring, 2015, p. 3).

Therefore, this research came as an attempt to develop ways of learning and engaging students in chemistry. It was proposed to apply the learning tool Happy Atoms and study its impact on improving first-year high school student's academic achievement and engagement to build models of chemical molecules.

Research Questions:

This research attempted to answer the following main question:

How does the mobile learning Happy Atoms tool affect first-year female high school students' academic achievement and learning engagement in building molecule models?

The following sub-questions branched out from the main question:

1. How does the learning tool Happy Atoms affect first-year female high school students' academic achievement in building molecule models?
2. How does the learning tool Happy Atoms affect first-year female high school students' behavioral engagement in building molecule models?
3. How does the learning tool Happy Atoms affect first-year female high school students' cognitive engagement in building molecule models?
4. How does the learning tool Happy Atoms affect first-year female high school students' emotional engagement in building molecule models?

Research Aim:

This research aims to reveal the effect of the learning tool Happy Atoms on first-year high school student's academic achievement and behavioral, cognitive, and emotional engagement while teaching them how to build chemical particle models in chemistry class.

Research Importance:

The Ministry of Education was among the sectors participating in the National Transformation Program. The ministry launched several educational initiatives to achieve this program. The program also sought to build educational goals, which included developing curricula and teaching methods while improving the environment that stimulates creativity and innovation. It also emphasized developing all students' essential knowledge and skills, including the basics of science (Burrows & Mooring, 2015, p. 19). In line with the urgent need to change traditional teaching methods and replace them with modern approaches to improve educational outcomes, this research may add the desired importance to each of:

- For researchers and educators: contribute to the development of the educational process and enrich the scholarly literature in educational technologies on the use of the mobile learning tool Happy Atoms in learning. It also opens the way for further studies on the Happy Atoms learning instrument to develop chemistry learning.
- For students: building a generation of thinkers with a remarkable ability to acquire knowledge and benefit from the recent technology and tools.
- For educational Curricula: developing educational curricula, providing appropriate techniques in teaching scientific knowledge, and contributing to finding means and methods that increase students' involvement in learning.
- For teachers: providing them with tools and technology that facilitate learning, building skills, and inspiring creativity.
- For school environment: creating a stimulating and attractive school environment for learning by employing the latest tools and techniques that bring real and meaningful learning.

Research Limitations:

1. Objective limits: this study was limited to the concepts (atoms, oxidation number, number of chemical bonds for each atom, molecules, molecular formula) found in the selected lesson.
2. Human and spatial limits: this study was limited to a random sample of first-year female students in high school in a public school in Makkah Al-Mukarramah Region.

Research Terms:

1. Effect:

Shehata and Al-Najjar (2003) defined it as "the outcome of a desirable or undesirable change that occurs in the learner as a result of the learning process" (p. 22).

The operational definition: The result achieved by the student after adapting the technology used to improve his learning and involvement.

2. Happy Atoms learning tool:

An interactive educational tool combining a digital application with physical models allows learners to discover the world of molecules practically and efficiently (McCoy, 2016, p. 5).

The operational definition: This tool combines a specific mobile application and physical and digital elements of the atoms. So, students can build physical models of many molecules by linking the physical atoms with magnetic bonds. Then, the students direct the tablet's camera into the physical models after installing the Happy Atoms application.

3. Learning Engagement:

Engagement in learning was defined by Astin (1999) as the amount of mental and physical energy a student devotes to academic experiences.

4. Models:

A model is a representation of a target or a system. It may or may not be conceived by a set of physical realities. Models also can be different entities, objects, ideas processes, phenomena, and their systems. They help to understand abstract concepts and theories with the real phenomena (Oh & Oh, 2011, p. 1114).

5. <u>Chemical molecules:</u>

Zhang defined it as combining at least two atoms in a specific order linked together by chemical forces known as chemical bonds, and the molecule can consist of the same atoms or different atoms in exact fixed proportions (Chang, 2008, p. 3).

The operational definition: Three-dimensional tangible objects help students visualize abstract concepts of molecules, identify the types and number of bonds between their constituent atoms, and interactively link them with a digital application.

Research Variables:

- Independent variable: the Happy Atoms learning tool.
- Dependent variable: academic achievement and behavioral, cognitive, and emotional engagement.

The Research Community and its Sample:

The research population: All female students in the first year of high school in Makkah Al-Mukarramah public schools.

The study sample: A random selection of (20) first-year female students in high school in a public school in north Makkah Al-Mukarramah city.

Research Tools:

Data was collected using the following tools:

1. Pretest and post-test: to identify how students have acquired the required scientific concepts.
2. Observation card: to track participants' engagement (behavioral, cognitive, and emotional engagement) while they build chemical molecule models using the Happy Atoms tool.

Research Procedures:

1. Defining the problem based on previous studies related to the variables of the current research.

2. Choosing a random sample of first-year female students in high school in a public school.
3. Preparing a training workshop for the female students to learn how to deal with the Happy Atoms tool and application and providing a guide explaining how to use this tool.
4. Designing an observation card to measure the engagement (behavioral, cognitive, and emotional) of female students while learning chemical molecule models.
5. Designing a test (pre-and post) to identify the extent to which students acquire the required scientific concepts.
6. Collecting and analyzing data using appropriate statistical methods and then interpreting them.
7. Extracting results and writing suggested recommendations.

Theoretical Framework and Previous Studies:

In this section, several concepts related to the variables of the current research are clarified, namely chemical molecule models, the Happy Atoms learning tool, academic achievement, and learners' engagement during learning.

First: Models of Chemical Molecules:

Modern chemistry is based on the atomic theory developed by the English scientist John Dalton in 1808 and built on essential assumptions about the nature of matter. One of these assumptions is the elements consist of atoms where the atoms of one element are similar in their properties. The atoms of any element differ from the atoms of the other component. These atoms can unite with each other in whole numbers to form compounds, and this happens through a chemical reaction that includes the union and separation of atoms and their rearrangement again (Chang, 2008, p. 3). Based on this theory, we find that the basic building blocks of chemistry begin with atoms and molecules that are fundamental units in building all materials.

Teaching chemistry relies intensely on educational aids, as it provides sensory experiences that support the absorption of many facts and concepts. Among these methods is what is known as educational models, which are three-dimensional figures representing real or abstract things (Al-Zahrani, 2017, p. 14). Syed and Hifzullah (1985) explain many of the capabilities available in the models, which increase the student's ability to visualize and express. Some of these capabilities are that the models help in:

1. Representation of something enormous that we cannot move.
2. Representation of something infinitely small and that cannot be seen.
3. Represent dangerous things that we cannot learn directly.
4. Clarify abstract ideas and values.

The images of the models differed over the years, so they were initially in the form of drawings. Then, computer-generated image models were used, and recently computers and tablets have been integrated into two- or three-dimensional models. Along with the advances in educational technologies, new ways to illustrate the molecular shape were provided, which indicates the simultaneous development and interest in learning science (McCollum et al., 2016, p. 14).

Models in their various forms provide an essential and vital aspect of thinking processes during learning, as they help represent scientific information, explain facts, describe ideas, and visualize abstract scientific concepts (Mendonca & Justi, 2014, p. 213). Educational models are like paving foundations to speed up students' imagination, visualization, and logical thinking. They also enhance the ability to retain information for a long time, open new horizons to learning, provide experiments and opportunities for discovering the world and develop the ability to address and solve problems. These all happen once atoms and abstract microscopic particles have become a model in the learners' hands.

The topic of molecular structures is one of the most essential topics in chemistry. However, most students struggle to understand their concepts and properties correctly due to the inability to see the atoms and their interactions with other atoms. Therefore, atoms and molecules include many abstract and complex concepts that are hard to imagine (Cai, Wang & Chiang, 2014, p. 31). Molecular models are essential to grasp different related topics, such as the type and number of atoms that make up a molecule, the number of bonds formed between them, the type of these bonds, and the geometry of the molecule in space. Therefore, computer-based activities and simulations will help students study and grasp these topics (Uyulgan & Akkuzu, 2016, p. 62).

First-year high school students need to know precisely the type of elements and atoms that make up molecules and their numbers depending on the number of valence electrons present in each atom according to its electronic distribution. They also need to recognize the number of bonds each atom forms, find an optimal way to name it and write its chemical formulas correctly. In this sense, we find that many studies have sought to search and pay attention to finding the best methods for teaching chemistry, including:

Al-Zahrani's study (2017) examined the effect of using two- and three-dimensional animations in acquiring some abstract chemical concepts. These abstract concepts are related to separating covalent bonds, which depend on realizing the three dimensions of a molecule, visualizing, and imagining how to arrange atoms in space. The results indicated a positive effect of 3D animation in acquiring chemical concepts. Another study aimed to identify students' learning experiences using different educational techniques to represent molecular shapes. So, three representational techniques were used: fixed printed images, plastic models in conjunction with selected images, and converting images using touch screen technology such as iPads. By comparing these three technologies, the results showed that convertible images on the iPad device are the best option for enhancing spatial awareness. The results also indicate that the iPad provides more chemical problem-solving strategies (McCollum et al., 2016, p. 2).

From the preceding, many studies are interested in chemistry, emphasizing the necessity of studying abstract concepts and trying to benefit from computer and wireless technologies in modeling and explaining through the three dimensions. Developing students' knowledge is vital to enhancing their skills and increasing their motivation to learn chemistry.

Second: Happy Atoms as a mobile learning tool:

1. Mobile Learning:

The term mobile learning appeared as a significant result of the emergence of mobile devices that rely on wireless communication, considered part of e-learning. Mobile learning aims to practice learning activities regardless of time and place (Al-Halfawi, 2011, p. 152). Mobile learning objects and contents are usually created based on mobile design principles, such as presenting materials in small chunks, flexible materials, and designing materials with a learner-centered approach (Demir & Akpinar, 2018, p. 13). Numerous studies have been concerned about clarifying the concept of mobile learning; one of them identifies it as a dynamic learning process that allows learners to collaborate with their teachers using mobile devices such as smartphones, tablets, or any wireless devices available to learners (Sharples, Taylor, & Vavoula, 2005, p. 8)

The spread of mobile devices, increasingly in many modern societies, has many advantages, including changes in learning and performance methods. Presenting learning content through small mobile devices will also affect the cognitive concepts of the learners and enable them to move freely during an educational journey dedicated to them at any time and place (Traxler, 2007, p. 7). Mobile learning has many unique characteristics, such as:

- Its ability to satisfy the urgent need for learning. It enables the learner to obtain solutions and information he needs at any time.

- Encourage learners to take the initiative in acquiring knowledge by providing relevant information when requesting that knowledge.
- Ease of communication with others and ease of movement between sources of information.
- Providing educational activities that are integrated with the educational content and instructions. Thus, learners can practice the required exercises and learn synchronously or asynchronously (Chen, Kao, & Sheu, 2003, p. 2).

2. Happy Atoms:

American professor Jesse Schell, with the help of designer Yotam Heimberg, presented the learning tool Happy Atoms to change the traditional way of teaching chemistry. This practical tool has been produced by the American company Shell Games (McCoy, 2016, p. 4). Happy Atom is an interactive educational tool that combines a digital application with a set of physical models. It allows learners to discover the world of molecules practically and efficiently. These physical models consist of colored plastic balls representing different atoms held by magnets illustrating the molecules. A digital application is available on all mobile devices, whether operating on the operating system (IOS) for Apple devices or the Android operating system. The idea of the learning tool Happy Atoms is based on students assembling molecules using plastic balls, as in Figure (1).

Figure (1): Creating molecules from plastic atoms.

Then, the mobile device's camera scans each atom's colors and chemical symbols. It collects information so students can see what they have built, as in Figure (2). Then, the application presents facts designed through educational media such as videos and pictures. The learning tool Happy Atoms is an example of mobile learning using mobile devices like smartphones and tablets.

Figure (2): Detection of the identity of molecules by the digital application

The Happy Atoms is concerned with various topics in the study of chemistry, including atomic structure, properties of elements, how they are organized in the Periodic Table, identification of ionic and covalent bonds formed between atoms during the formation of compounds, Lewis structure, molecular structure, and types of chemical reactions. This tool aims to change the traditional way of teaching chemistry. These topics in chemistry failed to capture learners' imaginations by the ordinary teaching methods, causing deficiencies in understanding and discouraging experimentation and discovery. In contrast, the Happy Atoms tool can indicate the total number of electrons around the nucleus of an atom, including the outer valence electrons. Its elements also contain binding sites or spots on the nucleus that indicate the number of bonds that can form during the formation of the molecule. It also includes the Periodic Table of the elements through which the stability of the elements can be observed when they have a complete outer shell of electrons.

Third: Academic achievement

Mobile learning is based on the learner-centered approach. It allows students to quickly access and interact with the content according to their needs. It encourages students to respond to learning activities and exposes diverse ways of learning. All these and other features of mobile learning increase academic achievement, as revealed in various studies (Demir & Akpinar, 2018, p. 21). For example, research studied the development of scientific abilities among high school students. The study utilized e-learning applications (multimedia) by presenting illustrations, video clips, and watching experiments about the Electrochemistry Unit. The results showed the effectiveness of this program and the superiority of the experimental group over the control group in scientific thinking and mastering the required concepts (Alharbii, 2017, p. 1160)

Other studies focused on tracking the impact of using computer applications and mobile devices in learning chemistry topics. Cai, Wang & Chiang (2014) studied the augmented reality (AR) to facilitate understanding the infinitesimal things. They also seek to improve teaching methods and tools. The researchers recommended using mobile technologies as a remedial educational tool for other chemistry contents, especially topics requiring students to memorize abstract concepts and structures. Also, using mobile games designed for chemistry can help students to form deep knowledge of chemistry. Games in chemistry also enhance students' twenty-first-century skills and increase their motivation in chemistry more than traditional methods (Lay & Osman, 2018, p. 10).

Many studies have been very interested in tracking computer technology's and mobile devices' impact. The study by Uyulgan & Akkuzu (2016) was conducted on undergraduate students to examine their knowledge of the concepts of molecular structures. The study emphasized the importance of paying attention to the topic of molecular structure and building its foundation in the curricula for the high school level. The researchers recommended using three-dimensional materials to help students develop their mental models.

<u>Fourth: Engaging in Learning:</u>

In more than two decades, student engagement in learning has grown from simple interest in the classroom to a combination of cognitive, emotional, and behavioral components that increase motivation to learn (Lei, Cui, & Zhou, 2018, p. 525). In the theory of student development, the scientist Alexander Astin presented an essential concept of engagement, defined as the amount of psychological and physical energy a student devotes to academic experiences (Astin, 1999, p. 518). Engagement in learning means active participation in classroom activities and tasks that facilitate learning and prevent any behaviors that detract from learning (Baker, Clark, Maier & Viger, 2008, p. 1876). Engaging is related to the time and effort students spend on activities of learning outcomes (Kuh, 2009, p. 2). Engagement also means the extent to which students are engaged in academic activities related to school, curriculum, and the pursuit of learning goals (Christenson et al., 2012, p. 22). It reflects learners' participation and interaction with others or educational content through verbal expression or thinking (Dixson, 2015, p. 2). There are three basic dimensions of engagement in learning:

1- Emotional or affective involvement is represented in the student's interactions and positive attitudes with his learning, friends, teachers, and school.
2- Behavioral engagement is represented in the time of active participation of students in the classroom and extra-curricular activities.
3- The cognitive engagement of the student is represented in the organized and effective implementation of learning strategies and methods (Christenson et al., 2012, p. 56).

Many studies have focused on examining students' involvement in their learning because of its profound influence on academic achievement. Arnold's study (2018) intended to describe the impact of mobile device technology on students' engagement with each other and their engagement with teachers and resources in the learning environment. The results indicated that using tablets in the learning environment has expanded the students' abilities to communicate and engage in learning. Fundamentally, mobile devices have changed the nature of learning interactions, how students process information, and how they acquire long-term knowledge. It also developed the students' higher-order thinking skills.

Another research examined mobile phone technologies' impact on student engagement during lectures. They found that students were academically engaging (Dobbins & Denton, 2017, p. 548). Another study aimed to understand how mobile phones can increase student learning and promote higher levels of engagement among students with the lesson and the content of physical and chemical properties of the elements (Lowe, 2017, p. 26). The results showed that the students were more motivated and engaged in the lessons in which mobile technologies were used, and they desired to learn more from these devices.

Recent developments in mobile technology have provided learners with the opportunity to improve their ability to communicate with others in different contexts, to find ways to acquire, build, and exchange knowledge, and to enhance their interactions with others (Northey, Bucic, Chylinski & Govind, 2015, p. 177). Another experimental study identified the effectiveness of using a training program based on mobile learning. This study examined engaging in learning. The tools were a scale of learning engagement skills in its three dimensions (cognitive, behavioral, and affective) and an observation card for designing digital learning objects. The results of this study indicated that this program contributed to improving the level of engagement in learning and the skills of creating digital learning objects (Abdul Majeed, 2014, p. 20).

From the previous, many studies sought to develop students' behavioral, cognitive, and emotional engagement using different methods and techniques, including mobile technology. These studies have also shown the effectiveness of mobile devices in developing students' academic achievement and engagement skills in general learning. All of that shows the possibility of using mobile devices as tools to increase students learning, promote engagement, and enhance their interaction with the academic content, in addition to other positive aspects. However, educational techniques must be utilized to support all students' potential for engagement and participation.

Research Method and Procedures:

This section presents the research methodology, the research community, the sample, data collection tools, validity and reliability, the instructional design used in applying the learning tool Happy Atoms, research procedures, and research data analysis methods to obtain results.

Research Methodology

The current research followed the experimental approach with a quasi-experimental design. The descriptive method was relied upon for detailed descriptions. A pretest and post-test were applied to identify the student’s academic achievement. An observation card was used to record students’ engagement while building models of chemical molecules. The researchers of this study believe these are the appropriate ways to know the role of the independent variable on the dependent variables.

The Experimental Design:

The study included one experimental group, as shown in the following Table (1).

Table (1): Experimental design of the research

Group	Measurement	Intervention	Measurement
Experimental group	A pretest	Using a learning tool, Happy Atoms, to build models of chemical molecules.	Posttest Observation card

The Instructional Design:

The instructional design links theoretical sciences with applied sciences. It increases the chances of success when teachers adapt the educational process following the learners' needs, abilities, and tendencies. After examining many instructional design models in the educational literature, the Al-

Mushaiqah model was applied. It includes five stages: the analysis stage, the preparation stage, the try-out stage, the utilization stage, and the evaluation stage.

1. The analysis stage:

The instructional design model begins with the analysis phase, which includes five issues: learners' analysis, educational needs analysis, learning environment analysis, scientific material analysis, and educational objectives analysis.

2. Preparation stage:

It is the initial preparation stage for the learning tool Happy Atoms. It was a workshop for teaching students how to deal with this tool. In addition, this study's measures have been prepared, which include the observation card and the pretest and post-test.

2.1. Workshop

The workshop's content is derived from the Happy Atoms user guide. The following are the details of the workshop in terms of defining its objectives, location, content, and materials needed for its implementation.

<u>Workshop objectives:</u>

1. The student learns how to use Happy Atoms till they master it.
2. Helping the student understand abstract concepts tangibly and embody them through the tool.
3. Building the student's confidence in her ability to learn how to make chemical models by herself.
4. Clarify the behavioral, cognitive, and emotional objectives implicitly.
5. Provide the student with tips to help her build complex chemical models correctly.

<u>Workshop location:</u>

The workshop was held in the science lab, containing a data show.

Workshop PowerPoint presentation explaining the objectives of the program.

Materials needed to carry out the workshop:

1. Plastic atom models from Happy Atoms.
2. An iPhone that has the Happy Atoms app installed.

2.2. Observation Card:

In the preparation stage, the research measure represented in the observation card was also designed. This card was prepared for first-year students to evaluate their behavioral, cognitive, and emotional engagement while building models of chemical molecules using the learning tool Happy Atoms. The sample, consisting of (20) female students, was divided into four groups. Each group consisted of 5 female students. The researchers observed each group and documented their engagement. It tracks students' engagement using the learning tool Happy Atoms. The card included (19) items divided into three axes (behavioral engagement, cognitive engagement, and emotional engagement). The first axis is related to behavioral engagement and contains (7) items. The second axis is related to cognitive engagement and has (6) items. The third axis is related to emotional involvement and contains (6) paragraphs. The observation card was drafted according to the Three Likert System: a score (3) means the degree of proficiency is high, a score (2) means the degree of proficiency is medium, and a score (1) means the degree of proficiency is low.

Validity of the observation card:

The card was presented to four arbitrators and specialists in educational technologies at King Abdulaziz University. They ensure the clarity of the card’s paragraphs, the integrity of its linguistic formulation, the extent to which it relates to the axis, and suitability for its purpose. Then, the observation card was modified based on their suggestions.

<u>Observation card stability:</u>

The card's stability was confirmed by applying it to an exploratory sample of (9) female students in the first year of high school, who were distributed into three groups. Its stability was verified in two ways:

1. Alpha Cronbach's Calculation.
2. The agreement of the observers.

The following Table (2) shows the results of the Alpha Cronbach for each axis of the card and the card as a whole.

Table (2): Results of the Cronbach's alpha equation

serial number	axis	The number of paragraphs	Cronbach's Alpha
1	Behavioral engagement	7	0.89
2	Cognitive engagement	6	0.95
3	Emotional involvement	6	0.72
4	The card as a whole	19	0.96

The value of Alpha Cronbach's in Table (2) ranges between (0.72 and 0.95) for the three axes, which indicates its stability and statistical acceptance. The result of Alpha Cronbach also shows a high correlation between the paragraphs of the card, which means the validity and stability of the observation card for application to the research sample.

The stability percentage of the observation card was also found by evaluating the students once by the researcher and once by another chemistry teacher. And then calculate the number of times of agreement and disagreement between the researcher's evaluation and the chemistry teacher's evaluation. Then, the stability ratio was calculated by using Cooper's equation, which:

$$\text{Stability ratio} = \frac{(\text{Agreement a number of times})}{(\text{Disagreement a number of times} + \text{Agreement a number of times})} * 100$$

The following Table shows the stability ratios between the evaluations of the two observations for the three groups of the exploratory sample.

Table (3): Persistence ratios

axis	The number of times the agreement	The number of times the difference	Persistence ratio
Behavioral engagement	20	1	95.2
Cognitive engagement	15	3	83.3
Emotional involvement	18	-	100
The card as a whole	53	4	92.9

It is clear from the above Table that the stability ratios between the scores recorded by the researcher and the scores recorded by the chemistry teacher are higher than (70), which indicates objectivity in the evaluation and that the coefficients of agreement are reliable. At the end of the assessment of the validity and reliability, the observation card became in its final form.

2.3. Test:

The researchers prepared a pretest and post-test. The tests aim to show students' acquisition of the required scientific concepts. The tests were designed according to the following:

1. Determine the scientific necessary concepts in building molecules.
2. Initial preparation for the pre and post-test forms.

Validity of the test:

The pretest and post-test were presented to three arbitrators and specialists in teaching chemistry. They ensure the clarity of the test’s paragraphs, the integrity of its linguistic formulation, the extent to which it relates to the subject, and its suitability for different purposes. Then, the researchers modified the questions based on their suggestions.

3. Experimental Phase:

Initially, the tool was introduced, and students were trained to use it. A workshop was held to show students how to correctly use the Happy Atoms tool's digital application and physical items.

Researchers delivered the safety instructions in the (PowerPoint) slides during this workshop. The Happy Atoms learning guide was used to create this workshop's presentation. Then, practical training on the Happy Atoms tool was applied while answering the students' inquiries about it. Figures number (4), (5), and (6) show some of the students' work. After ensuring all students mastered Happy Atoms, experimentation on the tool became possible.

Figure (4)

Figure (5)

Figure (6)

- Figure 4: Molecular structure by material atoms.
- Figure 5: Photographing the molecule using the digital application on the mobile phone.
- Figure 6: The structural form of the molecule as it appears in the digital application.

4. 4 - Utilization Stage:

At this stage, the students were divided into four groups. Each group used the Happy Atoms tool on two consecutive days. As shown in Table (4) below.

Table (4): Illustrative of experimental and utilization stages

Days	Groups	Available tools	Place	Time
Wednesday	All the four groups	Introductory workshop about the Happy Atoms tool	Science Lab	45 min.
Sunday & Monday	Group (1) Group (2)	Each group has a physical Happy Atoms widget, iPhones. Papers were provided for writing the group's name and molecular formula and drawing the designed molecule		
Tuesday & Wednesday	Group (3) Group (4)			

The role of the researchers at this stage was to guide the educational process and take pictures of some compounds that were difficult to appear in the digital application, such as butanone compound and monosodium phosphate compound. The researchers also carefully observed the female students' behavioral, cognitive, and emotional engagement and recorded them according to the items on the observation card. A pretest and post-test were conducted to measure students' acquired knowledge.

5. 5 - The evaluation stage:

At this stage, the measurement tool results were recorded during this study, which will be clarified and discussed in the next section, along with recommendations and suggestions for future research.

Results:

The following is a presentation of the results considering the four research questions of this study, respectively:

<u>First question:</u> How does the learning tool Happy Atoms affect first-year female high school students' academic achievement in building molecule models?

To obtain precise results of the impact of using the learning tool Happy Atoms on students' acquisition of the required scientific concepts, a pretest and post-test were conducted. Then, the collected data were processed statistically. Table (8) shows the most important results of the test (pre-post):

Table (8): Paired Samples Arithmetic mean and standard deviation

Variables	N	Mean	Std. Deviation
Pretest	20	4.30	.923
Post-test	20	5.30	.801

From the Table above, there is a difference between the arithmetic means of the pretest and post-test, as the arithmetic mean value for the pretest was (4.30), while the value for the post-test was (5.30). It also shows a difference between the standard deviations of the pretest and post-test, where the value of the standard deviation for the pretest was (.923), then the value for the post-test became (0.801). A nonparametric statistical test that compares two paired groups, the Wilcoxon Sign-Rank Test, was applied.

Test Statistics

	post-test - pretest
Z	-3.819b
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

The above Table shows statistically significant differences between the pre and post-test for the groups. The result indicated that median post-test ranks for academic achievement were statistically significantly higher than the pretest ranks *(Z* = -3.819, *p* <.000). That shows the positive effect of using the Happy Atoms tool on students' acquisition of the required scientific concepts.

Second question: How does the learning tool Happy Atoms affect first-year female high school students' behavioral engagement in building molecule models?

The observation card contains seven items related to behavioral objectives. It was used to measure the extent of behavioral engagement among female students. Then, the results were recorded by scoring the degree of mastery (3, 2, or 1). Then, calculate the percentage of the number of female students according to their degrees of proficiency. Accordingly, all female students in the four groups had a high response to the required tasks, a high tracking of the instructions, an increased ability to choose the chemical elements, and an ability to implement the required task accurately. However, there was a difference in the speed of installation, as half of them had a high ability to install molecules quickly. In contrast, the other half had an average ability to do so. Most students also recorded an increased ability to draw complex molecules and install molecules accurately without errors, as shown in Table (5).

Table (5): Behavioral engagement of female students in the training program.

(where 75% means three groups of 4, 50% means two groups of 4, and 25% represents one group of 4)

Serial no.	Axis	Paragraphs	Groups				The percentage of female students in perfection
			1	2	3	4	
1	Behavioral engagement	Responding to required tasks	high	High	High	High	100% high
2		Follow directions received with assignments	high	High	High	High	100% high
3		The ability to select chemical elements consistent with the task	high	High	High	High	100% high
4		Accurately carry out the required task	high	High	High	High	100% high
5		The ability to quickly install	high	middle	Middle	High	50% high 50% middle
6		Rare installation errors	high	High	Middle	high	75% high 25% middle
7		The ability to draw the installed molecule	Middle	high	high	high	75% high 25% middle

<u>Third question:</u> How does the learning tool Happy Atoms affect first-year female high school students' cognitive engagement in building molecule models?

The observation card contained six items to answer this question. These six items related to cognitive engagement and reflected to which extent the students are cognitively involved. Data from the four experimental groups were collected. Accordingly, all students had a high ability to compare the designed molecules and an increased ability to evaluate the quality of those molecules. Most students could answer all the questions about describing and designing chemical molecules. Also, half of them had a high ability to apply higher levels of thinking and understanding during the description, synthesis, and prediction of the correct structure of the required molecules by writing and drawing the formula of the molecule. While the other half had an average ability in that, as shown in Table (6).

Table (6): Cognitive engagement of the students as groups in the training program

(where 75% means three groups of 4, 50% means two groups of 4, and 25% means one group of 4)

Serial no.	Axis	paragraphs	Groups				The percentage of female students in perfection
			1	2	3	4	
1	cognitive engagement	The correct answer to the questions asked	high	High	High	middle	75% high 25% middle
2		Being able to describe designed chemical molecules	high	High	High	middle	75% high 25% middle

3		Apply high levels of reasoning and understanding during description and synthesis	high	High	middle	Middle	50 % high 50% middle
4		Ability to compare designed particles	high	High	High	High	100% high
5		The ability to assess the quality of designed particles	high	High	high	High	100% high
6		Predicting the correct composition of the required molecules by writing and drawing the molecule formula	middle	High	Middle	High	50 % high 50 % middle

<u>Fourth question:</u> How does the learning tool Happy Atoms affect first-year female high school students' emotional engagement in building molecule models?

The observation card was also used to measure emotional engagement. The students' percentages according to their proficiency degrees were calculated. Accordingly, all the participants worked very actively in the required tasks. They interacted very actively with each other while accepting and exchanging opinions. They worked in a team spirit without feeling bored when performing these tasks. Their words and gestures indicated excitement, enthusiasm, interest, and desire to continue building and designing chemical molecules, as shown in Table (7).

Table (7): The emotional involvement of the female students in the training program

(where 75% means three groups of 4, 50% means two groups of 4, and 25% means one group of 4)

Serial no.	Axis	Paragraphs	Groups				The percentage of female students in perfection
			First	second	Third	Fourth	
1	emotional engagement	Actively work on the assigned task	High	High	High	high	100% high
2		Active interaction and exchange of opinions among students	High	High	High	High	100% high
3		Accept the opinions of others	High	High	High	High	100% high
4		Feeling bored when performing the task	Low	Low	Low	Low	100% low
5		There are words that indicate excitement or interest	High	middle	high	High	75% high 25% middle
6		The desire for continuity of construction and design	High	middle	high	middle	75 % high 25 % middle

Interpret and discuss the results:

Based on the results of the current study, there is a high positive impact on the academic achievement and behavioral, cognitive, and emotional engagement of female students while learning chemical molecules using the Happy Atoms tool. This result agrees with previous studies emphasizing the need to use mobile devices in teaching chemistry and abstract concepts. Due to the main features of mobile device and application applied here, they ease the assimilation and formation of complex topics in chemistry. Mobile learning also helps enhance the students' motivation and involvement in learning chemistry, such as the study of Cai, Wang & Chiang (2014) and Lay & Osman (2018).

The recorded observation shows that the students built different compounds using the physical objects and the digital application of the Happy Atoms tool. The following pictures had been taken from the digital application on the mobile devices of each group:

Figure (7)
Group Particles (1)

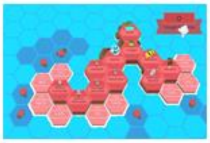

Figure (8)
Group Particles (2)

Figure (9)
Group Particles (3)

Figure (10)
Group Particles (4)

From the figures above, the modeled and built molecules using the Happy Atoms differed for the four groups. For the elements nitrogen and phosphorus, as in Figure (9), the fourth group created multiple molecules for the elements fluorine and chlorine, as in Figure (10). The students recorded the synthesized molecule's name and molecular formula on the worksheets. They painted it in different colors, showing the atoms contributing to the construction of each molecule. Below are pictures of some of the worksheets completed by each group.

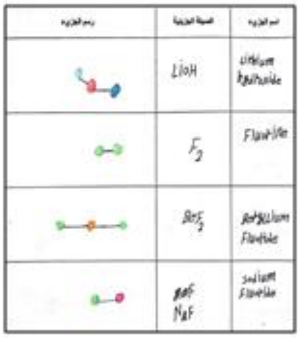

Figure (11): Group Worksheet (1)

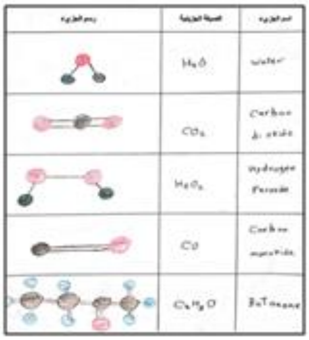

Figure (12): Group Worksheet (2)

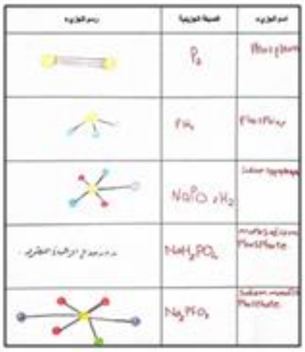

Figure (13): Group Worksheet (3)

Figure (14): Group Worksheet (4)

From these worksheets, the researchers noticed that the students in the four groups could write the molecular formula correctly, which indicates that the students understood the concept of the molecular formula and knew how to write it. The students were also able to present good drawings of the molecules, indicating their skillful ability to represent the shape of the molecules. Regarding cognitive engagement it may have an impact on students' acquisition of scientific concepts. It is consistent with studies that showed the positive effect of learning using mobile devices in enhancing students' understanding of educational content and increasing their interaction and engagement with lessons, such as Lowe's study (2017).

In addition to the contribution of the learning tool Happy Atoms to enhancing visualization and understanding of many concepts in chemistry, many opportunities have been provided to increase the involvement of students in building and learning molecules. The observation results confirmed the presence of a high level of emotional engagement among the students with the Happy Atoms during the construction of chemical molecules. The students show the desire and persistence to complete the assigned tasks. This result is consistent with many studies that have demonstrated the positive impact of mobile learning on student’s engagement during learning, such as the study of Pechenkina, Laurence, Oates, Eldridge & Hunter (2017) and Arnold’s study (2018). The results of this study show an increase in the student's emotional involvement represented in their active interaction with their peers and teachers.

The results also revealed a high response from the students to the required tasks and high tracking of the instructions related to the required tasks. The students showed a heightened ability to choose the correct chemical elements and to implement the required task accurately. Thus, the activities of molecule synthesis enhanced the aspects of behavioral engagement. That emphasizes the need for two- and three-dimensional images and models in teaching abstract concepts (McCollum et al., 2016, p. 3; Uyulgan & Akkuzu, 2016, p. 65). However, half of the students had a high ability to quickly install molecules, while the other half had an average speed. Most students also recorded an increased ability to draw complex molecules and install molecules accurately without errors.

In conclusion, employing mobile learning tools for teaching molecule models has enhanced the students' engagement with its three types (behavioral, cognitive, and emotional engagement) and immersed them in the learning environment. These engagement types have positively influenced the student's academic achievement, as shown in Lei, Cui, & Zhou's study (2018).

Research Limitations:

One of the limitations of this research is the high price of the learning tool Happy Atoms, so only two sets of the device were available. Other limitations are the sample size of 20 students from the first year of high school and the gender of students that the study applied to only female students. All these restrict the possibility of generalizing the results due to the small sample.

Recommendations:

Considering the results of the study, the researchers recommend the following:

- Studying the impact of using the learning tool Happy Atoms in teaching other subjects in chemistry, such as the types of chemical bonds and electronic distribution.
- Using research tools based on surveying students' opinions about the learning tool Happy Atoms, conducting interviews, and measuring satisfaction about using this tool in chemistry.
- Provide schools with the Happy Atoms tool and tablets to take advantage of this tool.
- Training teachers and students to use the learning tool Happy Atoms and providing the curricula with activities based on it.
- Using the learning tool Happy Atoms when teaching science at the elementary and intermediate levels.

Proposals for Future Research:

Considering the results of the current study and previous studies, the researchers propose the following topics:

- The effect of using the learning tool Happy Atoms on learning chemical bonds for secondary school students.
- Teachers and students’ attitudes toward using mobile technology in learning chemistry.

- The effect of using the learning tool Happy Atoms on students' high thinking skills.

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